FINAL REPORT

DESIGN, FABRICATION, TEST, AND DELIVERY OF ONE PROTOTYPE

HYDRAULIC POWER MANAGEMENT UNIT

NASA

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CONTRACT NAS 8-28483

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1.0 INTRODUCTION

The Hydraulic Power Management Unit (HPMU) was designed and developed under NASA Contract #8-28483 by the Bertea Corporation. The unit was designed between the periods of July and December, 1972.

The HPMU is essentially two identical selector valve systems of three slide valves each. Four hydraulic systems are supplied to the HPMU and the unit provides two hydraulic outputs. In the event that either or both of the two primary input hydraulic systems fail, the HPMU automatically switches the secondary standby hydraulic systems to provide output hydraulic power.

This report includes drawings, schematics, systems analysis and calculations, and performance test data to fulfill the contractual requirements.

2.0 DESIGN CONCEPT AND DISCUSSION

2.1 SCOPE OF WORK

Bertea Corporation has designed, fabricated, and delivered one prototype Hydraulic Power Management Unit (HPMU) for NASA, George C. Marshall Space Flight Center, Marshall Space Flight Center, Huntsville, Alabama. The purpose

2.0 DESIGN CONCEPT AND DISCUSSION (Continued)

2.1 SCOPE OF WORK (Continued)

of the HPMU is to serve as an interface between four hydraulic pumps and four servo actuators in order to provide hydraulic power redundancy for the servo actuators.

2.2 HPMU REQUIREMENTS

The basic requirements for the prototype hydraulic power management unit were as follows:

2.2.1 NORMAL OPERATION

Four pumps connected to four individual servo actuators.

2.2.2 FAILED PUMP CONDITION

Shutoff a pump when pressure drop (pressure to return) is less than 1500 psig. Divert servo actuator, which was connected to the failed pump, to one of the remaining three pumping systems. Sequence of shutoff and reconnection to be accomplished in less than .060 seconds.

2.2.3 SERVO ACTUATOR SHUTDOWN CONDITION

Individual remote controlled shutoff valves to be provided for each servo actuator. When an actuator is shutoff, its pressure and return lines are to be interconnected to form a piston by-pass path.

2.0 DESIGN CONCEPT AND DISCUSSION (Continued)

2.2 HPMU REQUIREMENTS (Continued)

2.2.4 INTERSYSTEM REQUIREMENTS

Mixing of hydraulic fluid from one system to another system is not permitted. (Lapped leakage on spool valves permitted.)

2.2.5 MECHANICAL REQUIREMENTS

Flight hardware restraints to be utilized in the design and construction of the unit. Size, weight, and environmental capabilities were to be considered.

2.3 CONCEPTUAL DESIGN

The Hydraulic Power Management Unit consists of:

1. Two main pump selector spool valves.
2. Four remote operated shutoff and by-pass valves
3. Housing

The unit was designed in accordance with NASA Drawing 50M25430. Design concept and installation for the unit is shown on Bertea Drawing 225700. The unit has been designed for a maximum pressure drop of 250 psig with 200 gpm flowing through the unit.

2.0 DESIGN CONCEPT AND DISCUSSION (Continued)

2.3 CONCEPTUAL DESIGN (Continued)

2.3.1 PUMP SELECTOR SPOOL VALVES

The pump selector spool valves are lap-fitted spool and sleeve valves and are spring-detented to center by caged springs. A differential pressure between two pumping systems of 1450 psig will overcome the spring preloads and start the spool to shuttle. When differential pressure reaches 1500 psig. The spool will be shuttled hardover. Whenever the systems differential pressures are less than 1500 psig, the caged spring will return the spool to center. The spool is made from 440C Stainless Steel and heat treated to RC 58-62. Each selector spool valve was split at the center for ease of manufacturing.

2.3.2 REMOTE SHUTOFF AND BY-PASS VALVE

The remote shutoff and by-pass valve consists of a spring loaded spool valve and a two-way microseal type solenoid valve with an upstream orifice. The valve was set to shuttle to the cylinder by-pass mode when the pressure in the spool chamber between the fixed orifice and solenoid valve decays to approximately 100 psig. The fixed orifice is a

2.0 DESIGN CONCEPT AND DISCUSSION (Continued)

2.3 CONCEPTUAL DESIGN (Continued)

2.3.2 REMOTE SHUTOFF AND BY-PASS VALVE (Continued)

Lee-Jet with filter screen for contamination protection. The spool and sleeve is made from 440C Stainless Steel RC 58-62. The solenoid valve is a standard Bertea unit which was built and qualified for use on the C-5A airplane flight control system.

2.3.3 HOUSING

The housings which contain all six of the spool valves and four solenoid valves are made from aluminum bar stock 2024-T651.

3.0 TEST PROGRAM AND RESULTS

3.1 TEST REQUIREMENTS

The test program accomplished on the Hydraulic Power Management Unit consisted of the following tests.

3.1.1 PRESSURE DROP VS. FLOW

Pressure drop vs. flow tests on each component will be run. Data will be utilized to extrapolate the corresponding pressure drop at 200 gpm.

3.0 TEST PROGRAM AND RESULTS (Continued)

3.1 TEST REQUIREMENTS (Continued)

3.1.2 RESPONSE TIME AND SHUTTLE PRESSURE

The response time to switch one failed servo actuator pumping unit will be run. Individual component switching pressure levels shall be measured.

3.1.3 NORMAL SYSTEM OPERATION

Normal system operation starting with all four pumping systems shutdown, then started, shutdown, and restarted shall be checked in order to insure that erroneous failures cannot occur.

3.1.4 REMOTE SHUTOFF

The remote shutoff and by-pass valve shall be checked for response time and pressure drop in the by-pass mode.

3.2 TEST SETUPS

3.2.1 PRESSURE DROP VS. FLOW TESTS

The test setups for accomplishment of the pressure drop vs. flow tests for the HPMU is shown Figures 3-1 and 3-2.

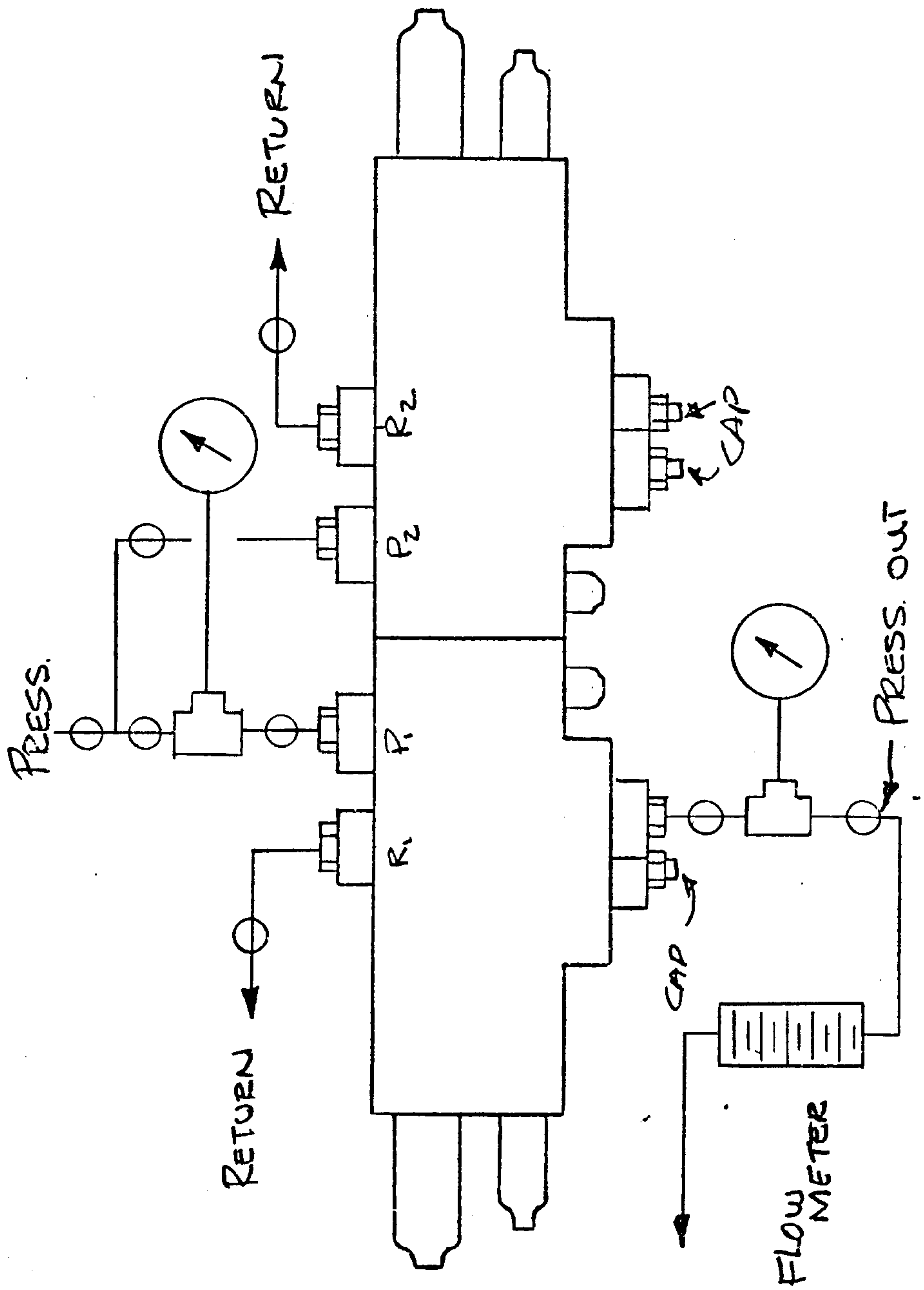

FIGURE 3-1

TEST SETUP

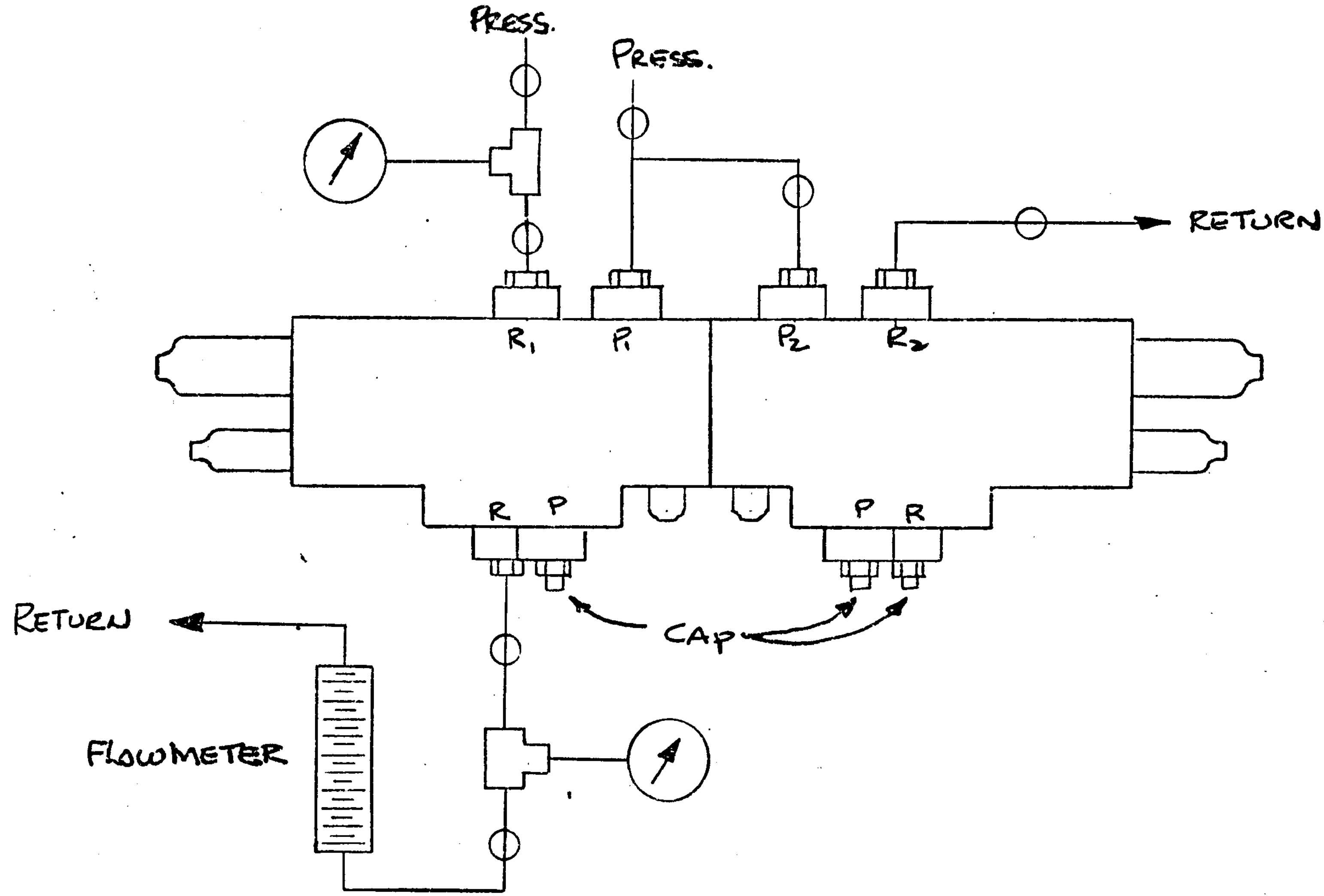

FIGURE 3-2

TEST SETUP

3.0 TEST PROGRAM AND RESULTS (Continued)

3.2 TEST SETUPS (Continued)

3.2.2 FAILURE SWITCHING AND RESPONSE TIMES

The test setups for accomplishment of the shuttle valve switching due to loss of volt system pressure and the time response for switching is shown in Figures 3-3 and 3-4.

3.2.3 NORMAL SYSTEM OPERATION

Test setup shown in Figure 3-1.

3.2.4 BY-PASS VALVE OPERATION

The test setup for the by-pass valve operation is shown in Figure 3-3 and 3-4.

3.2.5 PROOF PRESSURE

The proof pressure setup is shown in Figure 3-5.

3.3 TEST RESULTS

3.3.1 PRESSURE DROP VS. FLOW TESTS

The graphs in Figures 3-7 through 3-10 show the pressure drop vs. flow tests for two complete systems.

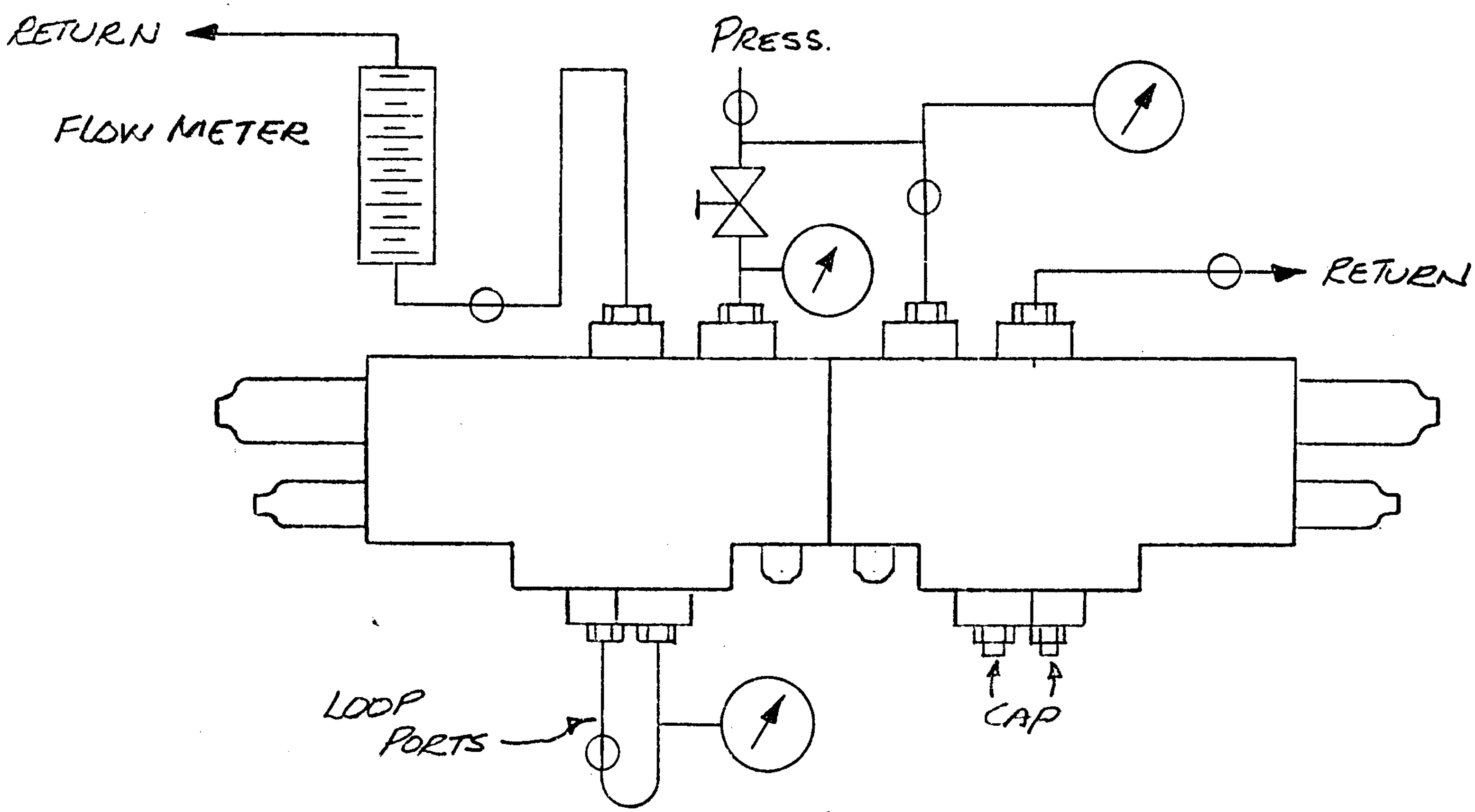

FIGURE 3-3

TEST SETUP

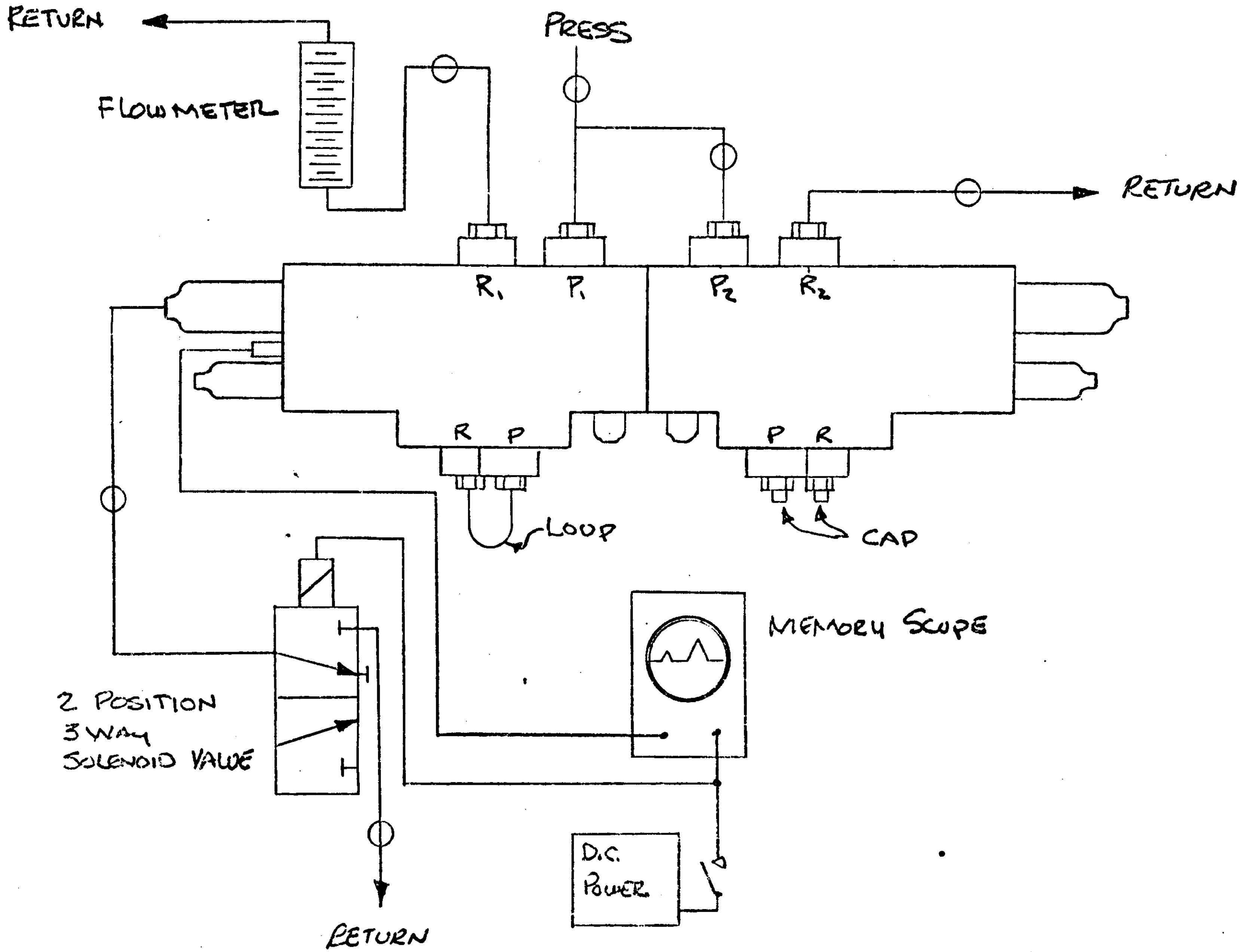

FIGURE 3-4
TEST SETUP

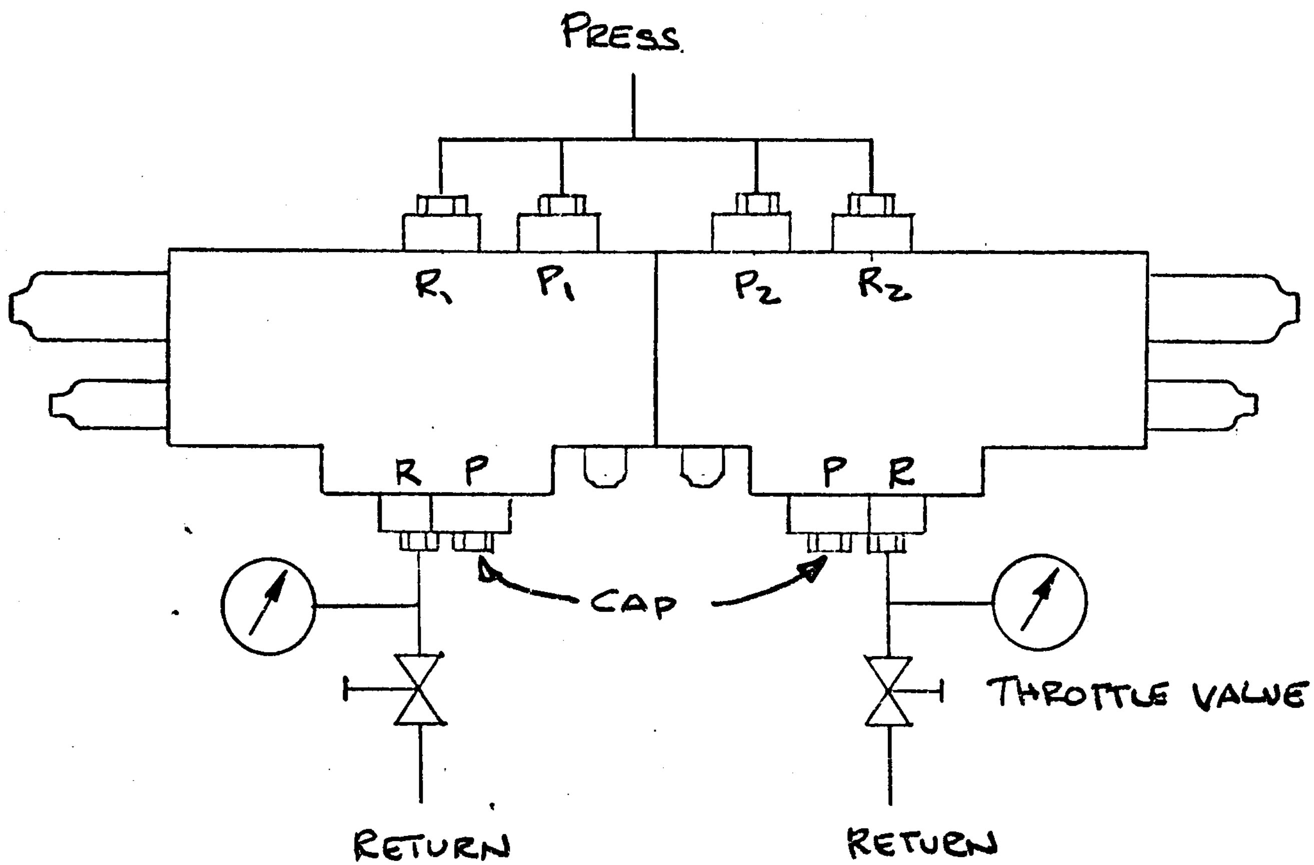

FIGURE 3-5

TEST SETUP

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

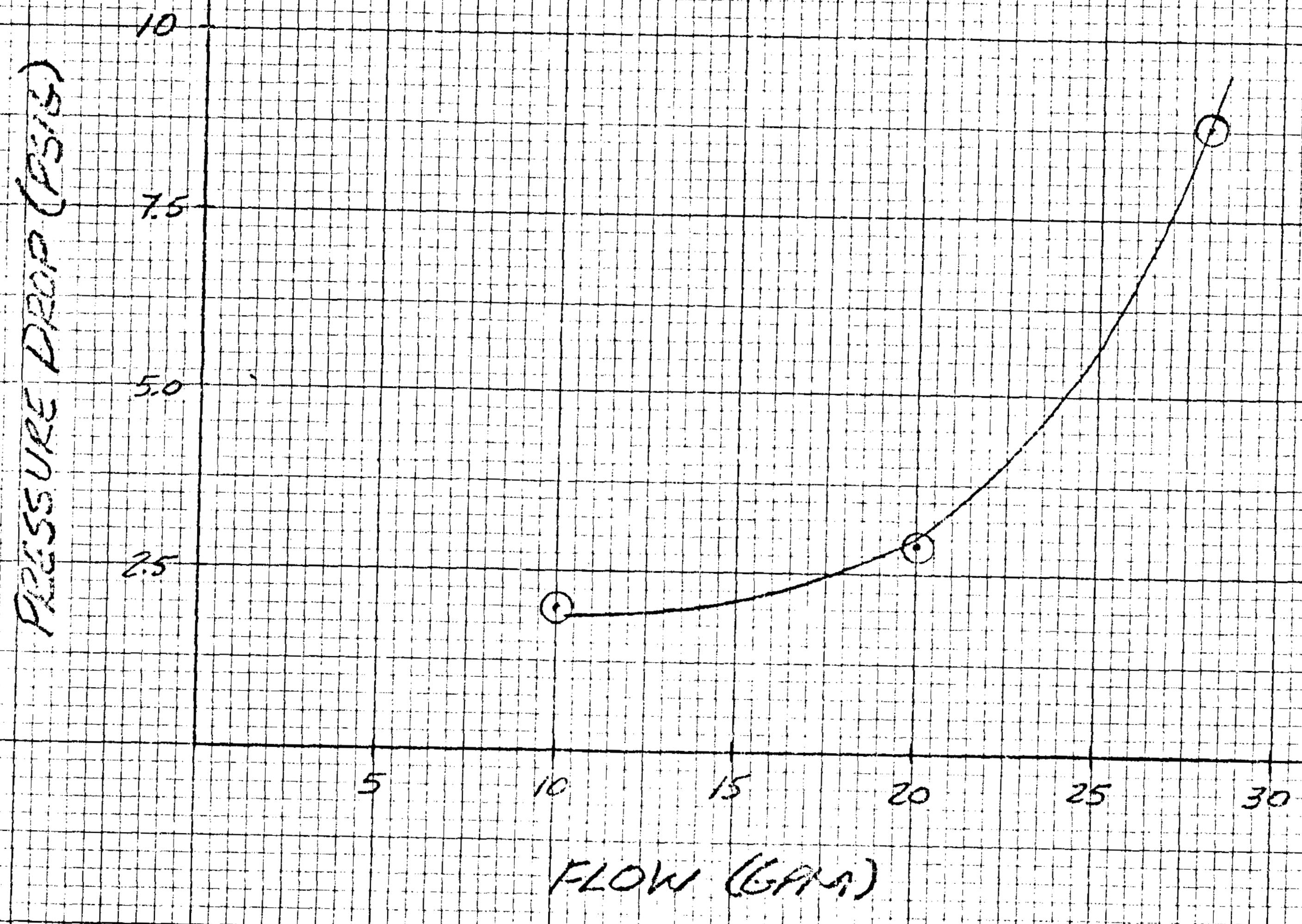

FIGURE 3-7

SYSTEM #1 PUMP PRESS TO LOAD PRESS DROP

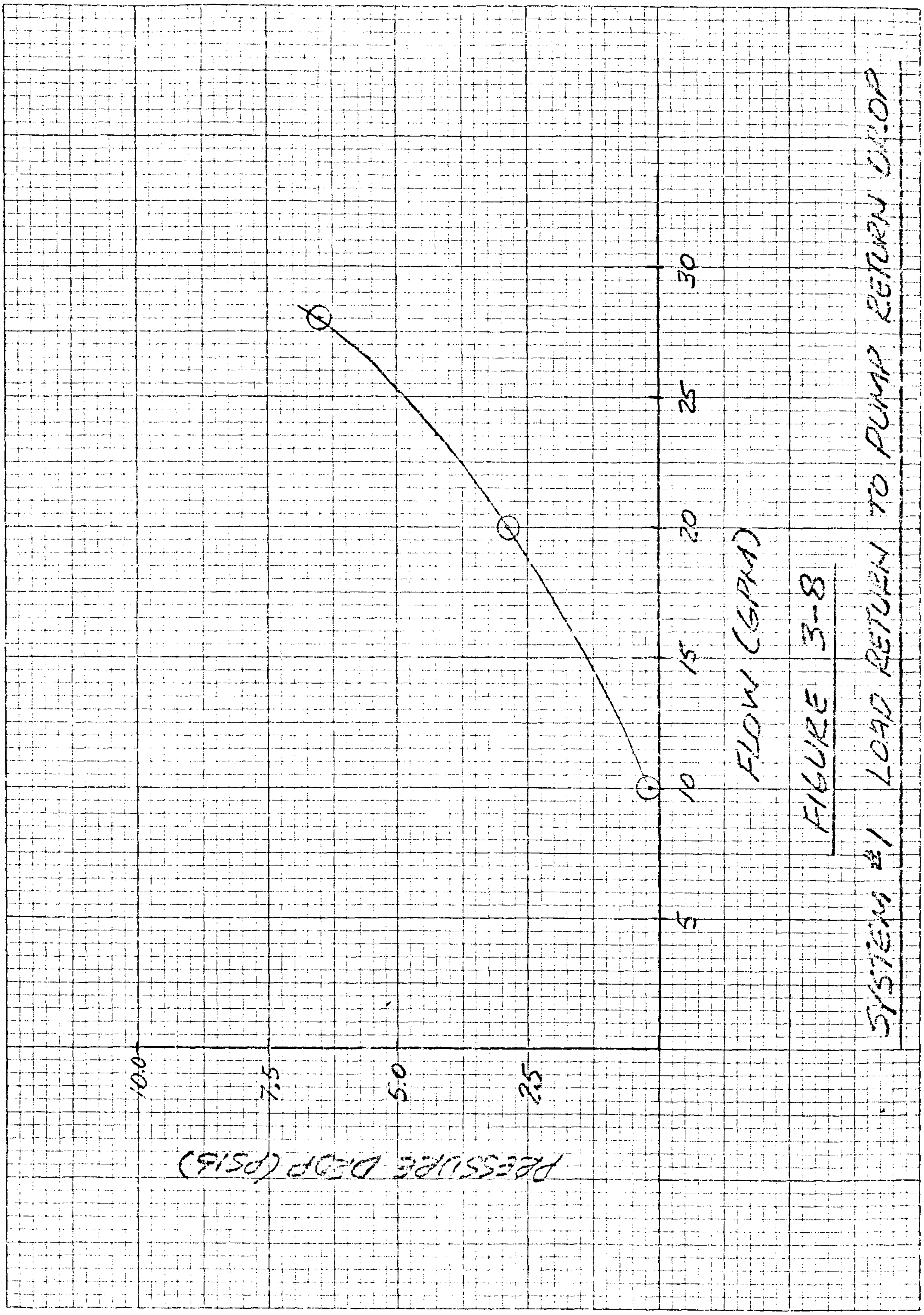

FIGURE 3-8

SYSTEM #1 LOAD RETURN TO PUMP RETURN DROP

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

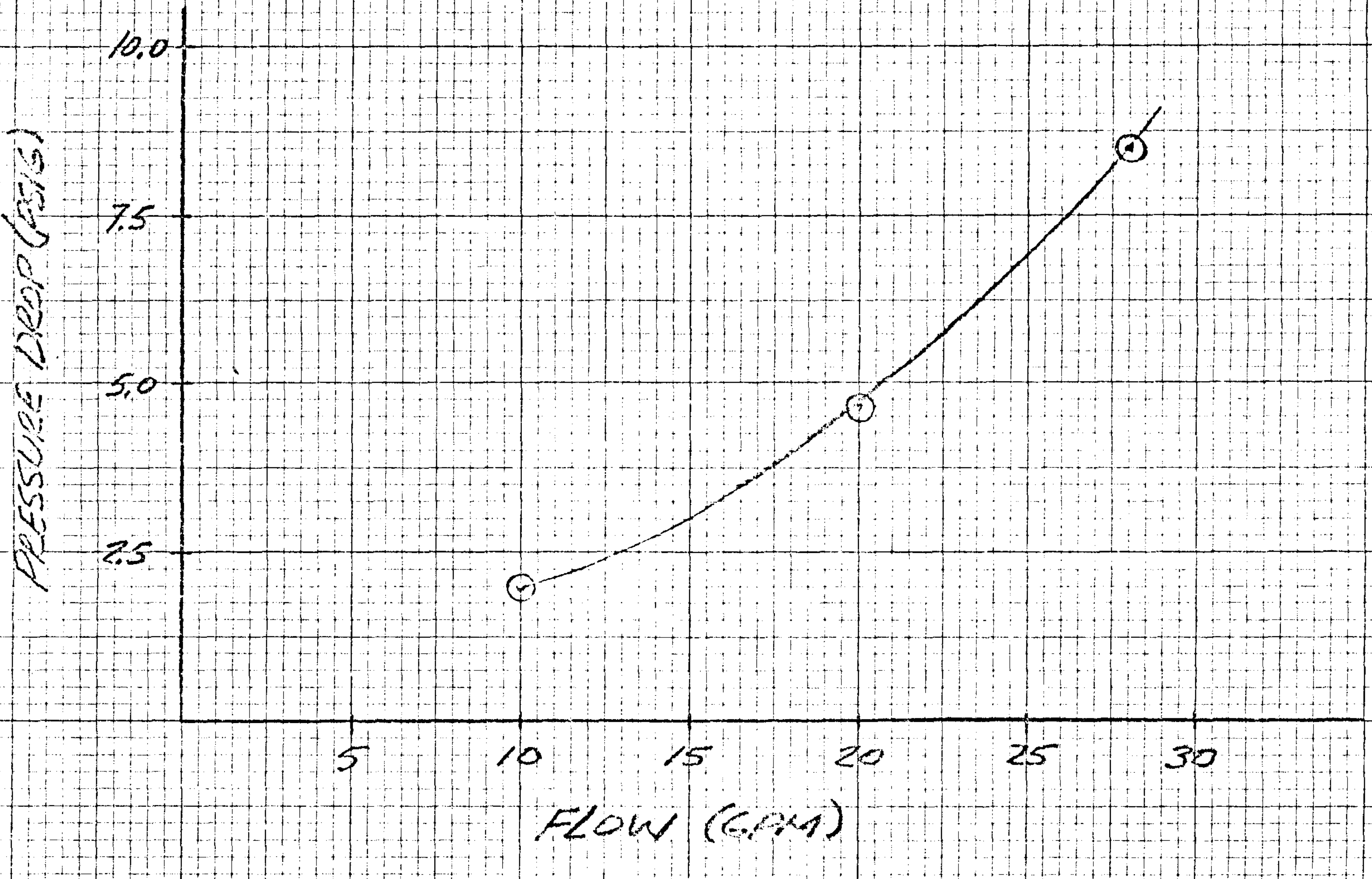

FIGURE 3-9

SYSTEM #2 PUMP PRESS. TO LOAD PRESS DROP

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH
EUGENE DIETZGEN CO.
MADE IN U. S. A.

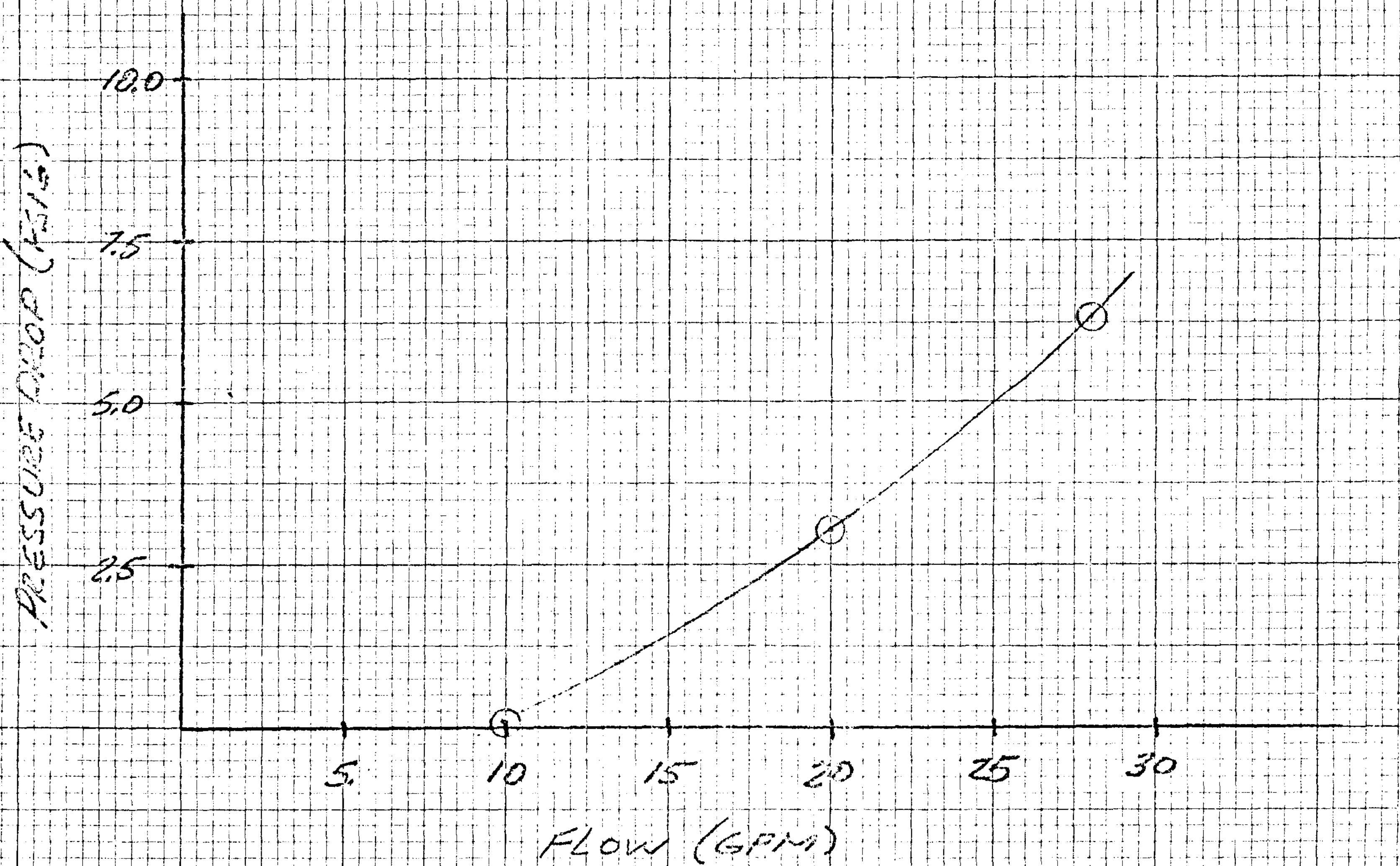

FIGURE 3-10

SYSTEM #2 LOAD RETURN TO PUMP RETURN DROP

3.0 TEST PROGRAM AND RESULTS (Continued)

3.3 TEST RESULTS (Continued)

3.3.2 RESPONSE TIME AND SHUTTLING PRESSURE

The response times and shuttling pressures for the main shuttle valves are shown on the data sheet in Figure 3-11.

3.3.3 NORMAL SYSTEM OPERATION

The unit was operated normally without any indication of failures.

3.4 BY-PASS VALVE OPERATION

The solenoids were actuated with 110 VAC successfully to cause a by-pass condition on the respective pump loads. Initially all loads were by-passed until a pump pressure of 100 psig occurred which actuated the by-pass valves to allow normal system operation.

3.5 PROOF PRESSURE

The unit was pressurized at 4500 psig for three minutes. The unit was successfully operated at the completion of the test without any evidence of performance degradation.

SYSTEM NUMBER	RESPONSE TIME (MILLISECONDS)	SHUTTLING PRESSURE (PSIG)
#1	54.0	1540
#2	62.0	1470
#3	58.0	1490
#4	67.0	1530

FIGURE 3-11

DATA SHEET - RESPONSE TIME AND SHUTTLING PRESSURES

4.0 FAILURE MODE AND EFFECT ANALYSIS

A Failure Mode and Effect Analysis for the Hydraulic Power Management Unit is presented herein. Refer to the schematic in Figure 4-1 for the various items or nomenclature.

FAILURE ITEM	FAILURE	EFFECT
1	SYSTEM PRESSURE #1 DROPS BELOW 1500 PSI	SHUTTLE SELECTOR VALVE SHUTTLES, BLOCKS SYSTEM #1 AND CONNECTS SYSTEM #2 TO LOAD NORMALLY ON SYSTEM #1
2	SYSTEM PRESSURE #2 DROPS BELOW 1500 PSI	SAME AS ABOVE EXCEPT SYSTEM #2 BLOCKED AND SYSTEM #1 CONNECTED TO LOAD NORMALLY ON SYSTEM #2
3	SYSTEM PRESSURES #1 AND #2 FAIL (ONE OR THE OTHER FAILS FIRST)	SELECTOR VALVE, ONCE SHUTTLED RECENTERS ITSELF SUCH THAT BOTH SYSTEMS ARE RECONNECTED
4	ORIFICE #1 PLUGGED	LOOKS LIKE SYSTEM #1 FAILURE. SHUTTLE VALVE SHUTTLES TO CONNECT LOAD ON SYSTEM #1 TO SYSTEM #2
5	ORIFICE #2 PLUGGED	BY-PASS VALVE SHUTTLES TO PUT LOAD ON SYSTEM #1 IN BY-PASS MODE
6	SOLENOID #1 FAILS OPEN	BY-PASS VALVES FOR SYSTEM #1 REMAINS IN BY-PASS MODE FOR LOAD ON SYSTEM #1
7	SOLENOID #1 FAILS CLOSED	BY-PASS VALVE CANNOT BE ACTUATED TO PROVIDE BY-PASS MODE FOR LOAD ON SYSTEM #1

4.0 FAILURE MODE AND EFFECT ANALYSIS (Continued)

FAILURE ITEM	FAILURE	EFFECT
8	SPRING #1 FAILS OR BREAKS	SHUTTLE SPOOL WILL JAM OR BE CAPABLE OF SHUTTLING AT SOME PRESSURE HIGHER THAN THE DESIGN REQUIREMENTS
9	SPRING #3 FAILS OR BREAKS	SHUTTLE SPOOL WILL JAM OR BE CAPABLE OF SHUTTLING AT SOME PRESSURE HIGHER THAN THE DESIGN REQUIREMENTS
10	SPRING #2 FAILS OR BREAKS	BY-PASS SPOOL NOT CAPABLE OF BY-PASSING LOAD WHEN SOLENOID VALVE IS ENERGIZED
11	SPRING #4 FAILS OR BREAKS	BY-PASS SPOOL NOT CAPABLE OF BY-PASSING LOAD WHEN SOLENOID VALVE IS ENERGIZED
12	ORIFICE #3 PLUGGED	LOOKS LIKE SYSTEM #2 FAILED. SHUTTLE VALVE SHUTTLES TO CONNECT LOAD ON SYSTEM #2 TO SYSTEM #1
13	ORIFICE #4 PLUGGED	BY-PASS VALVE SHUTTLES TO PUT LOAD ON SYSTEM #2 IN BY-PASS MODE
14	SOLENOID #2 FAILS OPEN	BY-PASS VALVE FOR SYSTEM #2 REMAINS IN BY-PASS MODE FOR LOAD ON SYSTEM #2
15	SOLENOID #2 FAILS CLOSED	BY-PASS VALVE FOR SYSTEM #2 CANNOT BE ACTUATED TO PROVIDE BY-PASS OPERATION FOR LOAD ON SYSTEM #2

4.0 FAILURE MODE AND EFFECT ANALYSIS (Continued)

FAILURE ITEM	FAILURE	EFFECT
16	MAIN SHUTTLE VALVE JAMMED SLIDE	VALVE FAILS TO SHUTTLE, LOSS OF BOTH PRIMARY AND SECONDARY SYSTEMS FAILURE CONSIDERED IMPROBABLE BECAUSE MINIMUM DRIVING FORCE IN 500 POUNDS
17	BY-PASS VALVE JAMMED SLIDE IN NON BY-PASS POSITION	FAILED SYSTEM DOES NOT BY-PASS
18	BY-PASS VALVE JAMMED SLIDE IN BY-PASS POSITION	OPERATING SYSTEM BY-PASSED FAILURE IMPROBABLE MINIMUM DRIVING FORCE IS 6200 POUNDS

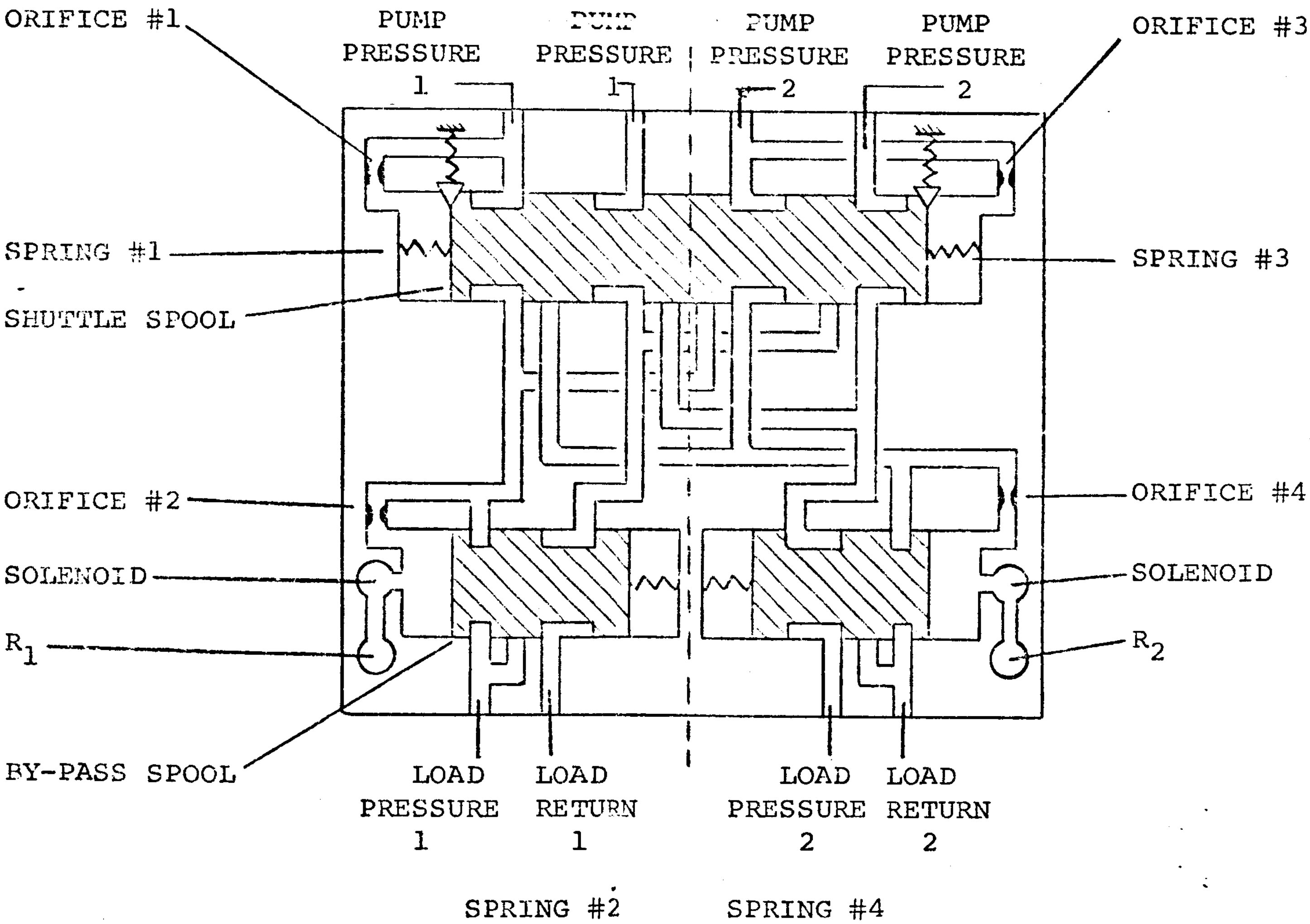

FIGURE 4-1

NOMENCLATURE SCHEMATIC - FMEA